XII. *Experiments and Obſervations in an heated Room*

By Charles Blagden, *M. D. F. R. S.*

Redde, Feb. 16, 1774. ABOUT the middle of January, ſeveral gentlemen and myſelf received an invitation from Dr. GEORGE FORDYCE, to obſerve the effects of air heated to a much higher degree than it was formerly thought any living creature could bear. We all rejoiced at the opportunity of being convinced, by our own experience, of the wonderful power with which the animal body is endued, of reſiſting an heat vaſtly greater than its own temperature; and our curioſity was not a little excited to obſerve the circumſtances attending this remarkable power. We knew, indeed, that of late ſeveral convincing arguments had been adduced, and obſervations made, to ſhew the error of the common opinions on this ſubject; and that Dr. FORDYCE had himſelf proved the miſtake of Dr. BOERHAAVE (a) and moſt other authors, by ſupporting many times very high degrees of heat, in the courſe of a long train of important experiments; with which, and his moſt philoſophical concluſions from them, every lover of ſcience muſt earneſtly wiſh that he may ſoon favour the public. In the mean time time, I am happy in an opportunity of laying before this So-

(a) Elem. Chemiæ, tom. I. p. 277, 278.

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ciety the following ſhort account of ſome of theſe experiments, and of the views with which they were undertaken; for the particulars of which I am obliged to Dr. FORDYCE himſelf.

DR. CULLEN long ago ſuggeſted many arguments to ſhew, that life itſelf had a power of generating heat, independent of any common chemical or mechanical means; for, before his time, the received opinions were, that the heat of animals aroſe either from friction or fermentation (b). Governor ELLIS in the year 1758 obſerved (c), that a man can live in air of a greater heat than that of his body; and that the body, in this ſituation, continues its own cold. The Abbé CHAPPE D'AUTEROCHE informs us, that the Ruſſians uſe their baths heated to 60° (d) of REAUMUR's thermometer, about 160 of FAHRENHEIT's, without taking notice, however, of the heat of their bodies when bathing. With a view to add further evidence to theſe extraordinary facts, and to aſcertain the real effects of ſuch great degrees of heat on

(b) To do further juſtice to the philoſophy of this moſt ingenious and reſpectable profeſſor, I muſt here declare, that during my ſtay in Edinburgh, from the year 1765 to 1769, the idea of a power in animals of *generating cold* (that was the expreſſion) when the heat of the atmoſphere exceeded the proper temperature of their bodies, was pretty generally received among the ſtudents of phyſic, from Dr. CULLEN's arguments; in conſequence of which I applied a thermometer, in a hot ſummer-day, to the belly of a frog, and found the quickſilver ſink ſeveral degrees: a rude experiment indeed, but ſerving to confirm the general fact, that the living body poſſeſſes a power of reſiſting the communication of heat.

(c) Philoſophical Tranſactions, vol. L. p. 755.

(d) Voy. en Siberie, tom. I. p. 51.

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the human body, Dr. FORDYCE tried the following experiments.

He procured a *ſuite* of rooms, of which the hotteſt was heated by flues in the floor, and by pouring upon it boiling water; and the ſecond was heated by the ſame flues, which paſſed through its floor to the third. The firſt room was nearly circular, about ten or twelve feet in diameter and height, and covered with a dome, in the top of which was a ſmall window. The ſecond and third rooms were ſquare, and both furniſhed with a ſky-light. There was no chimney in theſe rooms, nor any vent for the air, excepting through crevices at the door. In the firſt room were placed three thermometers; one in the hotteſt part of it, another in the cooleſt part, and a third on the table, to be uſed occaſionally in the courſe of the experiment: the frame of this laſt was made to turn back by a joint, ſo as to leave the ball and about two inches of the ſtem quite bare, that it might be more conveniently applied for aſcertaining the heat of the body, and ſeveral other purpoſes.

EXPERIMENT I.

In the firſt room the higheſt thermometer ſtood at 120°, the loweſt at 110°; in the ſecond room the heat was from 90° to 85°; the third room felt moderately warm, while the external air was below the freezing point. About three hours after breakfaſt, Dr. FORDYCE having taken off all his cloaths, except his ſhirt, in the third room, and being furniſhed with wooden ſhoes, or rather ſandals tied on with liſt, entered into the ſecond room, and ſtaid five

minutes in a heat of 90°, when he began to ſweat gently. He then entered the firſt room, and ſtood in the part heated to 110°; in about half a minute his ſhirt became ſo wet that he was obliged to throw it aſide, and then the water poured down in ſtreams over his whole body. Having remained ten minutes in this heat of 110°, he removed to the part of the room heated to 120°; and after ſtaying there twenty minutes, he found that the thermometer placed under his tongue, and held in his hand, ſtood juſt at 100°, and that his urine was of the ſame temperature. His pulſe had gradually riſen till it made 145 pulſations in a minute. The external circulation was greatly increaſed; the veins had become very large, and an univerſal redneſs had diffuſed itſelf over the body, attended with a ſtrong feeling of heat. His reſpiration, however, was but little affected. Here Dr. FORDYCE remarks, that the moiſture of his ſkin moſt probably proceeded chiefly from the condenſation of the vapour in the room upon his body. He concluded this experiment in the ſecond room, by plunging into water heated to 100°; and, after having been wiped dry, was carried home in a chair; but the circulation did not ſubſide for two hours, after which he walked out in the open air, and ſcarcely felt the cold.

EXPERIMENT II.

In the firſt room the higheſt thermometer varied from 132° to 130°; the loweſt ſtood at 119°. Dr. FORDYCE having undreſſed in an adjoining cold chamber, went into the heat of 119°; in half a minute the water poured down in ſtreams over his whole body, ſo as to keep that part of the floor

floor where he ſtood conſtantly wet. Having remained here fifteen minutes, he went into the heat of 130°; at this time the heat of his body was 100°, and his pulſe beat 126 times in a minute. While Dr. FORDYCE ſtood in this ſituation, a Florence flaſk was brought in, by his order, filled with water heated to 100°, and a dry cloth, with which he wiped the ſurface of the flaſk quite dry; but it immediately became wet again, and ſtreams of water poured down its ſides; which continued till the heat of the water within had riſen to 122°, when Dr. FORDYCE went out of the room, after having remained fifteen minutes in an heat of 130°; juſt before he left the room his pulſe made 139 beats in a minute, but the heat under his tongue, in his hand, and of his urine, did not exceed 100°. Here Dr. FORDYCE obſerves, that as there was no evaporation, but conſtantly a condenſation of vapour on his body, no cold was generated but by the animal powers. At the concluſion of this experiment, Dr. FORDYCE went into a room where the thermometer ſtood at 43°, dreſſed himſelf there, and immediately went out into the cold air, without feeling the leaſt inconvenience; on which he remarks, that the tranſition from very great heat to cold is not ſo hurtful as might be expected, becauſe the external circulation is ſo excited, as not to be readily overcome by the cold. Dr. FORDYCE has ſince had occaſion, in making other experiments, to go frequently into a much greater heat, where the air was dry, and to ſtay there a much longer time, without being affected nearly ſo much, for which he aſſigns two reaſons;

that dry air does not communicate its heat like air ſaturated with moiſture; and that the evaporation from the body, which takes place when the air is dry, aſſiſts its living powers in producing cold. It muſt be immediately perceived, that, beſides the principal object, theſe curious experiments throw great light on many other very important ſubjects of natural philoſophy.

January 23. The honourable Captain PHIPPS, Mr. BANKS, Dr. SOLANDER, and myſelf, attended Dr. FORDYCE to the heated chamber, which had ſerved for many of his experiments with dry air. We went in without taking off any of our cloaths. It was an oblong-ſquare room, fourteen feet by twelve in length and width, and eleven in height, heated by a round ſtove, or *cockle*, of caſt iron, which ſtood in the middle, with a tube for the ſmoke carried from it through one of the ſide walls. When we firſt entered the room, about 2 o'clock in the afternoon, the quickſilver in a thermometer which had been ſuſpended there ſtood above the 150th degree. By placing ſeveral thermometers in different parts of the room we afterwards found, that the heat was a little greater in ſome places than in others; but that the whole difference never exceeded 20°. We continued in the room above 20 minutes, in which time the heat had riſen about 12°, chiefly during the firſt part of our ſtay. Within an hour afterwards we went into this room again, without feeling any material difference, though the heat was conſiderably increaſed. Upon entering the room a third time, between five and ſix o'clock after dinner, we obſerved

ſerved the quickſilver in our only remaining thermometer at 198°(e): this great heat had ſo warped the ivory frames of our other thermometers that every one of them was broken. We now ſtaid in the room, all together, about 10 minutes; but finding that the thermometer ſunk very faſt, it was agreed, that for the future only one perſon ſhould go in at a time, and orders were given to raiſe the fire as much as poſſible. Soon afterwards Dr. SOLANDER entered the room alone, and ſaw the thermometer at 210°; but, during three minutes that he ſtaid there, it ſunk to 196°. Another time, he found it almoſt five minutes before the heat was leſſened from 210° to 196°. Mr. BANKS cloſed the whole, by going in when the thermometer ſtood above 211°; he remained ſeven minutes, in which time the quickſilver had ſunk to 198°; but cold air had been let into the room, by a perſon who went in and came out again during Mr. BANKS's ſtay. The air heated to theſe high degrees felt unpleaſantly hot, but was very bearable. Our moſt uneaſy feeling was a ſenſe of ſcorching on the face and legs; our legs particularly ſuffered very much, by being expoſed more fully than any other part to the body of the ſtove, heated red-hot by the fire within. Our reſpiration was not at all affected; it became neither quick nor laborious; the only difference was a want of that refreſhing ſenſation which accompanies a full inſpiration of cool air. Our time was ſo taken up with other obſervations that we did not

(e) This thermometer ſtands, near the boiling point, about a degree too high; the ſcale is FAHRENHEIT's.

count our pulſes by the watch: mine, to the beſt of my judgment by feeling it, beat at the rate of 100 pulſations in a minute, near the end of the firſt experiment; and Dr. SOLANDER's made 92 pulſations in a minute ſoon after we had gone out of the heated room. Mr. BANKS ſweated profuſely, but no one elſe; my ſhirt was only damp at the end of the experiment. But the moſt ſtriking effects proceeded from our power of preſerving our natural temperature. Being now in a ſituation in which our bodies bore a very different relation to the ſurrounding atmoſphere from that to which we had been accuſtomed, every moment preſented a new phænomenon. Whenever we breathed on a thermometer the quickſilver ſunk ſeveral degrees. Every expiration, particularly if made with any degree of violence, gave a very pleaſant impreſſion of coolneſs to our noſtrils, ſcorched juſt before by the hot air ruſhing againſt them when we inſpired. In the ſame manner our now cold breath agreeably cooled our fingers whenever it reached them. Upon touching my ſide, it felt cold like a corpſe; and yet the actual heat of my body, tried under my tongue, and by applying cloſely the thermometer to my ſkin, was 98°, about a degree higher than its ordinary temperature. When the heat of the air began to approach the higheſt degree which this apparatus was capable of producing, our bodies in the room prevented it from riſing any higher; and when it had been previouſly raiſed above that point, inevitably ſunk it. Every experiment furniſhed proofs of this: toward the end of the firſt, the thermo-

meter was ſtationary: in the ſecond, it ſunk a little during the ſhort time we ſtaid in the room: in the third, it ſunk ſo faſt as to oblige us to determine that only one perſon ſhould go in at a time: and Mr. BANKS and Dr. SOLANDER each found, that his ſingle body was ſufficient to ſink the quickſilver very faſt, when the room was brought nearly to its *maximum* of heat.

Theſe experiments, therefore, prove in the cleareſt manner, that the body has a power of deſtroying heat. To ſpeak juſtly on this ſubject, we muſt call it a power of deſtroying a certain degree of heat communicated with a certain quickneſs. Therefore in eſtimating the heat which we are capable of reſiſting, it is neceſſary to take into conſideration not only what degree of heat would be communicated to our bodies, if they poſſeſſed no reſiſting power, by the heated body, before the equilibrium of heat was effected; but alſo what time that heat would take in paſſing from the heated body into our bodies. In conſequence of this compound limitation of our reſiſting power, we bear very different degrees of heat in different mediums. The ſame perſon who felt no inconvenience from air heated to 211°, could not bear quickſilver at 120°, and could juſt bear rectified ſpirit of wine at 130°; that is, quickſilver heated to 120° furniſhed, in a given time, more heat for the living powers to deſtroy, than ſpirits heated to 130°, or air to 211°(f).

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(f) Theſe numbers are the reſult of ſome experiments which were made on the firſt of February, in a room where the heat of the air was 65°. Mr. BANKS

And we had in the heated room where our experiments were made, a ſtriking though familiar inſtance of the ſame. All the pieces of metal there, even our watch-chains, felt ſo hot, that we could ſcarcely bear to touch them for a moment, whilſt the air, from which the metal had derived all its heat, was only unpleaſant. The ſlowneſs with which air communicates its heat was further ſhewn, in a remarkable manner, by the thermometers we brought with us into the room, none of which at the end of twenty minutes, in the firſt experiment, had acquired the real heat of the air by ſeveral degrees. It might be ſuppoſed, that by an action ſo very different from that to which we are accuſtomed, as deſtroying a large quantity of heat, inſtead of generating it, we muſt have been greatly diſordered. And indeed we experienced ſome inconvenience; our hands ſhook very much, and we felt a conſiderable degree of languor and debility; I had alſo a noiſe and giddineſs in my head. But it was only a ſmall part of our bodies that exerted the power of deſtroying heat with ſuch a violent effort as ſeems neceſſary at firſt ſight. Our cloaths, contrived to guard us from cold, guarded us from the heat on the ſame principles. Underneath we were ſurrounded with an atmo-

BANKS and I found that we could bear ſpirits which had been conſiderably heated and were now cooling, when the thermometer came to the 130th degree; cooling oil at 129°; cooling water at 123°; cooling quickſilver at 117°. And theſe points were pretty nicely determined; ſo that though we could bear water very well at 123°, we could not bear it at 125°, an experiment in which Dr. SOLANDER joined us. And our feelings with reſpect to all theſe points, ſeemed pretty exactly the ſame.

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ſphere of air, cooled on one ſide to 98°, by being in contact with our bodies, and on the other ſide heated very ſlowly, becauſe woollen is ſuch a bad conductor of heat. Accordingly I found, toward the end of the firſt experiment, that a thermometer put under my cloaths, but not in contact with my ſkin, ſunk down to 110°. On this principle it was that the animals, ſubjected by M. TILLET to the intereſting experiments related in the Memoirs of the Academy of Sciences for the year 1764, bore the oven ſo much better when they were cloathed, than when they were put in bare: the heat actually applied to the greateſt part of their bodies was conſiderably leſs in the firſt caſe than in the laſt. As animals can deſtroy only a certain quantity of heat in a given time, ſo the time they can continue the full exertion of this deſtroying power ſeems to be alſo limited; which may be one reaſon why we can bear for a certain time, and much longer than can be neceſſary to fully heat the *cuticle*, a degree of heat which will at length prove intolerable. Probably both the power of deſtroying heat, and the time for which it can be exerted, may be increaſed, like moſt other faculties of the body, by frequent exerciſe. It might be partly on this principle that, in M. TILLET'S experiments, the girls who had been uſed to attend the oven bore, for ten minutes, an heat which would raiſe FAHRENHEIT'S thermometer to 280°: in our experiments, however, not one of us thought he ſuffered the greateſt degree of heat that he was able to ſupport.

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A principal uſe of all theſe facts is, to explode the common theories of the generation of heat in animals. No attrition, no fermentation, or whatever elſe the mechanical and chemical phyſicians have deviſed, can explain a power capable of producing or deſtroying heat, juſt as the circumſtances of the ſituation require. A power of ſuch a nature, that it can only be referred to the principle of life itſelf, and probably exerciſed only in thoſe parts of our bodies in which life ſeems peculiarly to reſide. From theſe, with which no conſiderable portion of the animal body is left unprovided, the generated heat may be readily communicated to every particle of inanimate matter that enters into our compoſition. This power of generating heat ſeems to attend life very univerſally. Not to mention other well known experiments, Mr. HUNTER found a carp preſerve a coat of fluid water round him, long after all the reſt of the water in the veſſel had been congealed by a very ſtrong freezing mixture. And as for inſects, Dr. MARTINE (g) obſerved, that his thermometer, buried in the midſt of a ſwarm of bees, roſe to 97°. It ſeems extremely probable, that vegetables, together with the many other vital powers which they poſſeſs in common with animals, have ſomething of this property of generating heat. I doubt, if the ſudden melting of ſnow which falls upon graſs, whilſt that on the adjoining gravel walk continues ſo many hours unthawed, can be adequately explained on any other ſuppoſition. Moiſt dead

(g) Eſſays Medical and Philoſophical, p. 331.

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ſticks are often found frozen quite hard, when in the ſame garden the tender growing twigs are not at all affected. And many herbaceous vegetables, of no great ſize, reſiſt every winter degrees of cold which are found ſufficient to freeze large bodies of water. It may be proper to add, that after each of the above mentioned experiments of bearing high degrees of heat, we went out immediately into the open air, without any precaution, and experienced from it no bad effect. The languor and ſhaking of our hands ſoon went off, and we have not ſince ſuffered the leaſt inconvenience.